

# Discovering the global landscape of problem-based learning and critical thinking: a bibliometric review

Yogalingam Subramaniam, Muzirah Musa

School of Educational Studies, Universiti Sains Malaysia, Pulau Pinang, Malaysia

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## ABSTRACT

This study seeks to explore recent trends in publications related to problem-based learning (PBL) and critical thinking (CT). It analyzes annual growth rate, document type, source, languages, and subject area to assess their impact. This study identified publications by countries, analyzed authorship, and highlighted the most active institutions. It examined prevalent PBL and CT themes by analyzing keyword occurrences, source titles, and abstracts. A bibliometric approach was used to map existing research on PBL and CT from the Scopus database. The data were analyzed through the VOSviewer software for data visualization, Microsoft Excel 365 for frequency analysis, and Herzing's Publish or Perish software for citation metrics. The findings demonstrated a growing combination of PBL and CT with an increasing demand. Articles, journals, English, and social sciences were the increasing types of publication documents (TP). The United States published the most documents. Donnelly, J. from Three Rivers Community was the top researcher in PBL and CT publications. Hong Kong Polytechnic University had the highest average citations per publication. The keyword "PBL" was frequently employed, and nursing education journals significantly impacted PBL and CT publications. Simultaneously, engineering and thinking skills were frequently employed terms in the title abstract and title field.

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## Corresponding Author:

Muzirah Musa

School of Educational Studies, Universiti Sains Malaysia

Pulau Pinang, Malaysia

Email: muzirah@usm.my

## 1. INTRODUCTION

Education generally encompasses problem-solving or preparation to resolve challenges, with teachers playing a crucial role in assisting students to appropriately answer questions or resolve challenges [1]. Students can memorize the content but might not understand or fully apply the acquired knowledge without teachers' guidance, which emphasizes the problem-based learning (PBL) importance [2]. Moreover, The PBL represented pioneered in a medical education program at McMaster University in Hamilton, Ontario, Canada introduced by Howard Barrows and colleagues in the 1960s [3]. While PBL was introduced to provide medical students to improve medical expertise, PBL was also promoted based on the belief of providing significant cognitive impacts on training doctors, including enhanced knowledge to integrate and apply fundamental scientific concepts to clinical contexts [4]. Hence, PBL illustrate a student-centered method [5], where students gain knowledge on a topic via group collaboration to resolve a challenge [6]. The PBL also improves knowledge and skills in real-world situations by engaging in various activities [7], such as collaboration, practical activities, and teamwork in small groups [8], which provides students with a more authentic learning experience for higher understanding and knowledge levels. Additionally, PBL encourages the growth of critical thinking (CT) and communication skills [9].

Broadly, CT involves an intellectual process of conceptualizing, applying, analyzing, synthesizing, and evaluating information acquired from observation, experience, and reflection to perform reasonable decisions on personal beliefs and actions [10], [11]. The CT is considered essential as the competence in critically is fundamental to the educational process [12]–[16]. The CT can produce an individual capable of resolving challenges and performing sound decisions. It requires a systematic and structured thought process to analyze and evaluate conclusions referring to the evidence, assumptions, and justified logic [17]. The skill is also pivotal for students to swiftly determine credible information, concentrate on effective learning, and remain highly attuned to real-world situations [16]. According to Darhim *et al.* [18], CT ability is a high-level thinking skill necessary to resolve challenges authentically, which should be inculcated to apply the skill in daily life [19]. Furthermore, technological advancement and social changes that increase daily life challenges necessitate CT as a vital complement for the future [20].

Past PBL studies concentrated more on the impacts and improvements in learning [21]–[25]. Nonetheless, relevant studies on PBL and CT patterns and trends were limited, which required further research to develop the latest strategies. Bibliometric analysis uses statistical methods to analyze publications in a specific field. This includes journal articles, books, and literature. It helps identify researchers' outputs and impacts, calculate journal impact factors and citation scores, and understand publication relationships [26], [27]. Bibliometric analysis also enables the determination of core research and relationships, making it a widely used method for analyzing large volumes of scientific data [26]–[28]. Study [29] conducted a bibliometric analysis from 1981 to 2021 in PBL research, wherein a total of 2,790 articles were analyzed and demonstrated a continuous increase in PBL publications. The United States of America (USA) emerged as the leading contributor and Van Der Vleuten CPM was identified as a prominent researcher in the field. Furthermore, majority publications were in the medical educational field. Meanwhile, keyword analysis indicated that most research focused on PBL teaching methods, applications, and innovations. PBL publications were primarily sourced from the Web of Science (WoS) database with the details of references, journals, researchers, institutions, countries, and annual publications.

The present study also conducted bibliometric analysis in PBL and CT from 1975 to 2023 to address three research questions: i) what are the current PBL and CT publication trends and impacts? ii) which are the most productive and influential PBL and CT countries, institutions, and authors? and iii) which are the most prevalent PBL and CT themes among scholars? Keyword analysis was also visually presented through multiple software, including R, VOSviewer, and Microsoft Excel 2019.

## 2. METHOD

The analyzed PBL and CT documents in the current study were obtained from the Scopus database, which is the largest abstract and citation database for peer-reviewed literature, which includes scientific journals, books, and conference proceedings. Scopus provides an extensive overview of global research across various fields such as science, technology, medicine, social sciences, and the arts, making it a valuable tool for tracking, analyzing, and visualizing research data [30], [31]. The database provides access to various subjects, document types, source titles, affiliations, keywords, and cited references for each publication. Scopus works with over 7,000 publishers, offering 23 million open-access articles, 28,000 active serial titles, and 94,000 affiliation profiles.

Both PBL and CT topics were searched on Scopus through the search field using the abstract, article title, as well as keyword. The employed search string represented TITLE-ABS-KEY (“problem-based learning” AND “critical thinking”) AND (LIMIT-TO (EXACTKEYWORD, “Problem-Based Learning”) OR LIMIT-TO (EXACTKEYWORD, “Problem-Based Learning”) OR LIMIT-TO (EXACTKEYWORD, “Problem-based Learning”) OR LIMIT-TO (EXACTKEYWORD, “PBL”). The search period was defined from 1995 to 2023 and no language restrictions were applied. All data were obtained from the database on December 20, 2023, with 1,109 identified and filtered records without discarding any collected records. The publication review followed the standard protocols of the preferred reporting items for systematic reviews and meta-analyses (PRISMA), with the procedure is presented in a flowchart as in Figure 1.

This study conducted a bibliometric analysis to measure and analyze publications indexed in the Scopus database [32]. Bibliometric analysis is a quantitative method used to identify publication trends within a particular field of study [33]–[36]. The current researcher employed VOSviewer version 1.6, Harzing's Publish or Perish (PoP) software, and Microsoft Excel 365. 20 software to fulfil all research objectives [37]. Microsoft Excel was used to calculate the publication frequencies, while Publish or Perish (PoP) was employed to analyze and evaluate academic publications and citation data. VOSviewer was employed to construct and generate images with bibliometric connections, with charts and graphs generated via Microsoft Excel 365.

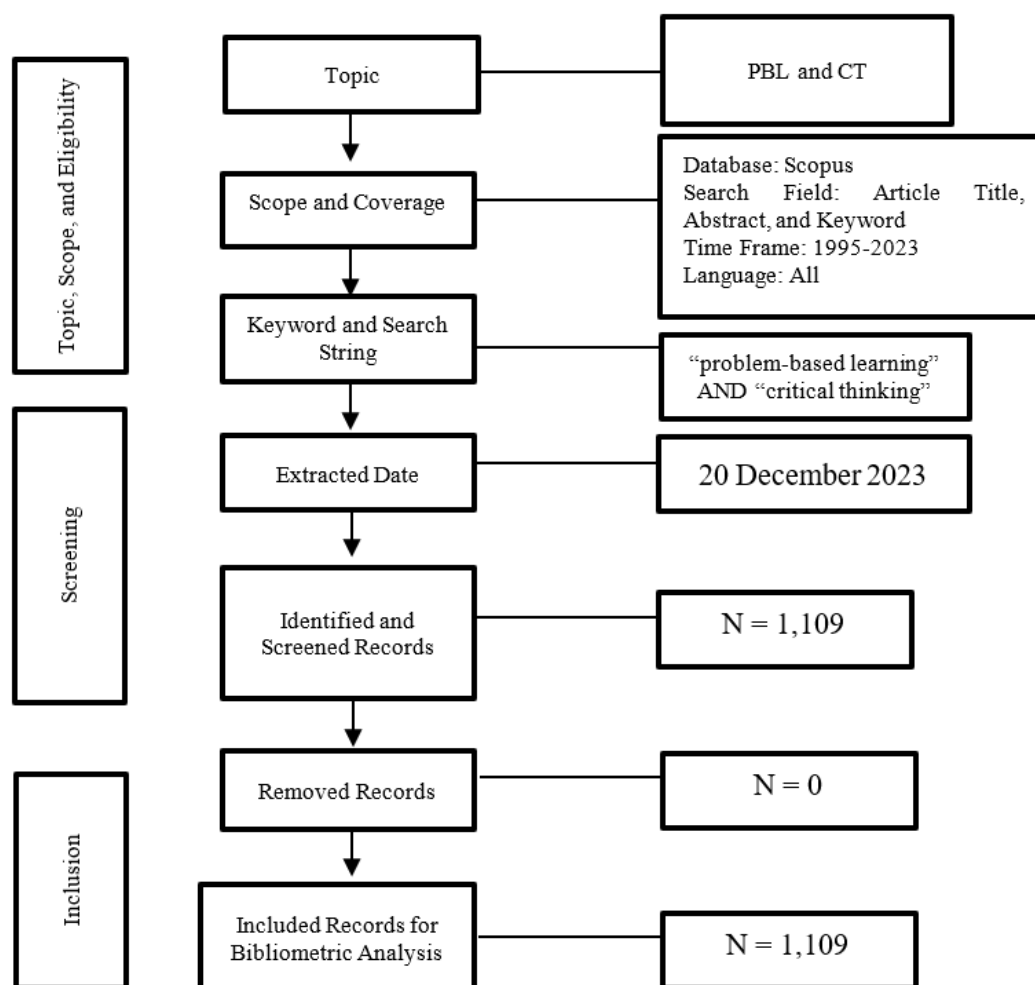


Figure 1. The flowchart according to the PRISMA

### 3. RESULTS

#### 3.1. Annual publication growth

Table 1 (see in Appendix) depicts the PBL and CT publication statistics from 1995 to 2023. The first publications in 1995 consisted of 3 documents indexed in Scopus. Less than 10 PBL and CT documents were discovered in the database between 1995 and 2002, whereas a gradual increase was determined from 2003 to 2019 with the publications' highest number within 2020 and 2021 at 101 (9.11%) and 109 (9.83%) respectively. The highest number demonstrated the high research focus on PBL and CT owing to increased funding and collaboration opportunities. Furthermore, PBL and CT gained attention from academics, shaping future research directions. Both approaches have evolved in teaching and learning, improving education overall. The increase was reflected in the average citations (C/P) with the growing relevance and influence of the topic in the academic and educational domains. The trend also indicated a shift towards more active learning, student-centered approaches, and the CT skills' development in educational practices.

Figure 2 illustrates the total citations (TC) and total publications (TP) from 1995 to 2024. Documents published in 2015 received a significantly high citation number, which achieved 1,592 with a C/P of 24.88. Nonetheless, the number decreased in 2016 to 671 with a C/P of 13.16 and remained below 1,000 from 2016 to 2023 with a C/CP ratio below 20. The latest publications encountered increasing competition for citations, which contributed to the low citation numbers.

#### 3.2. Document type

Table 2 portrays the number of PBL and CT publications by document type, in which the publication number of articles is significantly high at 765 (68.98%), followed by conference papers at 215 (19.39%), review papers at 91 (8.21%), book chapters at 15 (1.35%), and books at 1 (0.09%). The high percentage of article

publications indicated researchers' high commitment and the peer review process before publication encouraged researchers to publish and contribute high-quality research work. While articles are essential for theoretical development, the publication of other document types serves as an indicator of the need for practical implementation.

Table 3 illustrates the source types involved in PBL and CT publications, with journal publications significantly high at 890 (80.25%), followed by book series at 20 (1.80%), conference proceedings at 190 (17.13%), and books at 9 (0.81%). Journals are recognized for the rigorous review process and are frequently considered a standard for academic publication. Conference proceedings are also recognized among academicians, which provide a platform for researchers to present and discuss relevant work. Additionally, researchers and practitioners benefit from engaging with various publication sources to remain highly informed about the latest research developments and access a wide range of PBL and CT knowledge.

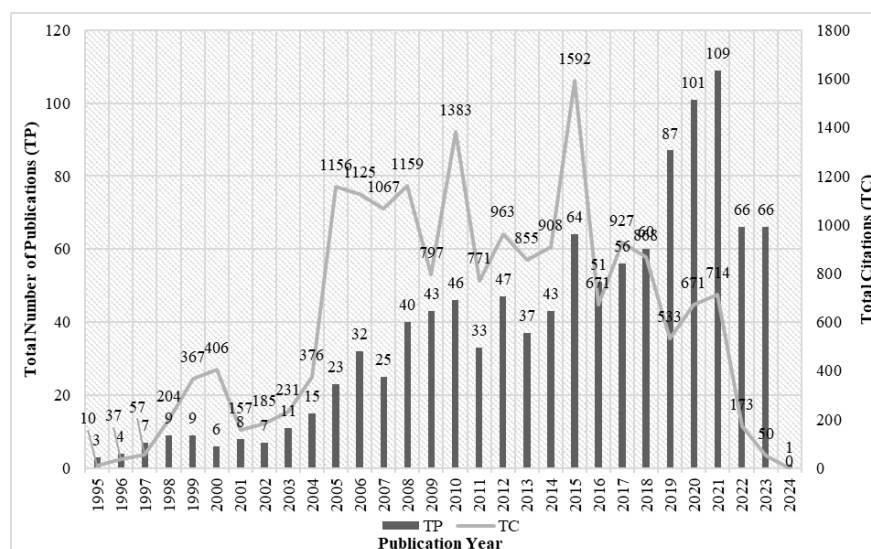


Figure 2. Total publications and citations by year

Table 2. Document types

| Document type    | Total publication | %     |
|------------------|-------------------|-------|
| Article          | 765               | 68.98 |
| Conference Paper | 215               | 19.39 |
| Review           | 91                | 8.21  |
| Book Chapter     | 15                | 1.35  |
| Note             | 8                 | 0.72  |
| Letter           | 6                 | 0.54  |
| Editorial        | 4                 | 0.36  |
| Short Survey     | 4                 | 0.36  |
| Book             | 1                 | 0.09  |

Table 3. Source types

| Source type           | Total publication | %     |
|-----------------------|-------------------|-------|
| Journal               | 890               | 80.25 |
| Conference proceeding | 190               | 17.13 |
| Book series           | 20                | 1.80  |
| Book                  | 9                 | 0.81  |

### 3.3. Document language

Table 4 demonstrates that 1067 (95.18%) publications are in English, which indicates a high prevalence of English as the primary medium for disseminating PBL and CT research. Simultaneously, a small number of publications are in other languages, such as Spanish, Portuguese, Chinese, and others. English is considered an international language, which leads researchers to publish in English. Research publications in English also facilitate the rapid dissemination process compared to other languages. researchers and practitioners who publish in English also benefit from increased citations of personal work.

Table 4. Publication languages

| Language   | Total publication | %     |
|------------|-------------------|-------|
| English    | 1067              | 95.18 |
| Spanish    | 21                | 1.87  |
| Portuguese | 9                 | 0.80  |
| Chinese    | 7                 | 0.62  |
| Korean     | 4                 | 0.36  |
| Turkish    | 3                 | 0.27  |
| French     | 2                 | 0.18  |
| Indonesian | 2                 | 0.18  |
| Greek      | 1                 | 0.09  |
| Italian    | 1                 | 0.09  |
| Malay      | 1                 | 0.09  |
| Polish     | 1                 | 0.09  |
| Russian    | 1                 | 0.09  |
| Swedish    | 1                 | 0.09  |

### 3.4. Subject area

Table 5 highlights the subject areas of publications, with social sciences taking the lead, accounting for the highest number of publications at 562 documents (50.68%). Consequently, the finding reflected the emphasis on PBL and CT. Moreover, publications in healthcare, engineering, computer science, and business suggested the flexibility and applicability of the concepts in various professional and academic fields. The high number of social science publications may be due to PBL's ability to offer real-world problem-solving, a skill highly valued in these disciplines. Students could develop CT skills by applying theoretical concepts to practical situations.

Table 5. Subject Area

| Subject area                                  | Total publication | %     |
|-----------------------------------------------|-------------------|-------|
| Social sciences                               | 562               | 50.68 |
| Nursing                                       | 265               | 23.90 |
| Medicine                                      | 209               | 18.85 |
| Engineering                                   | 128               | 11.54 |
| Computer science                              | 104               | 9.38  |
| Physics and astronomy                         | 81                | 7.30  |
| Biochemistry, genetics, and molecular biology | 56                | 5.05  |
| Health professions                            | 51                | 4.60  |
| Pharmacology, toxicology, and pharmaceuticals | 45                | 4.06  |
| Dentistry                                     | 38                | 3.43  |
| Business management and accounting            | 37                | 3.34  |
| Mathematics                                   | 34                | 3.07  |
| Materials science                             | 24                | 2.16  |
| Arts and humanities                           | 23                | 2.07  |
| Environmental science                         | 20                | 1.80  |
| Psychology                                    | 17                | 1.53  |
| Agricultural and biological sciences          | 16                | 1.44  |
| Multidisciplinary                             | 15                | 1.35  |
| Decision sciences                             | 10                | 0.90  |
| Earth and planetary sciences                  | 10                | 0.90  |
| Economics, econometrics, and finance          | 8                 | 0.72  |
| Immunology and microbiology                   | 7                 | 0.63  |
| Energy                                        | 5                 | 0.45  |
| Veterinary                                    | 5                 | 0.45  |
| Chemical engineering                          | 4                 | 0.36  |
| Chemistry                                     | 4                 | 0.36  |
| Neuroscience                                  | 4                 | 0.36  |

### 3.5. Publications by country

Table 6 demonstrates the number of publications by country, with only the top 5 countries considered. Particularly, the USA led in terms of publication quantity and impact in PBL and CT, which depicted an increase in the TP, NCP, TC, C/P, C/CP, h-index, and g-index. Other countries, namely Indonesia, Australia, Canada, and China, also provided significant contributions with unique strengths and impacts.

Table 6. Total publications by country

| Country   | TP  | NCP (%) | TC  | C/P  | C/CP  | h     | g  |
|-----------|-----|---------|-----|------|-------|-------|----|
| USA       | 398 | 35.89   | 354 | 8462 | 21.26 | 23.90 | 45 |
| Indonesia | 137 | 12.35   | 112 | 820  | 5.99  | 7.32  | 15 |
| Australia | 55  | 4.96    | 46  | 1313 | 23.87 | 28.54 | 20 |
| Canada    | 54  | 4.87    | 49  | 1321 | 24.46 | 26.96 | 20 |
| China     | 47  | 4.24    | 37  | 683  | 14.53 | 18.46 | 14 |

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; and g=g-index.

### 3.6. Authorship analysis

The data were analyzed based on the researchers, in which the Scopus search identified the top five researchers contributing the most to PBL and CT publications as in Table 7. Specifically, Donnelly, J. from Three Rivers Community College in the USA possessed 10 publications while Hanes from the New England Board of Higher Education in the USA possessed seven publications. Meanwhile, Juandi from Universitas Pendidikan Indonesia in Indonesia and Massa from Springfield Technical Community College in the USA published six articles respectively.

Figure 3 is a co-authorship visualization map based on authors with a minimum of one publication. The line thickness, font size, circle size, and color illustrate the correlation with another authors [38], which were analyzed via the VOSviewer software to display a visual map of bibliometric networks. Two co-authorship clusters were discovered, wherein Cluster 1 contained 17 items while Cluster 2 comprised four items. Chang, Bernard S. in Cluster 1 possessed a robust and positive relationship with Flanagan, John, Besche, Henrike C., and Schwartzstein, Richard M. Meanwhile, Schwartzstein, Richard M. in Cluster 2 possessed a robust and positive relationship with Chang, Bernard S. and Richard, Jeremy. Figure 4 illustrates a co-authorship visualization map based on organizations with a minimum of one document. Cluster 1 portrayed a relationship between critical care, cardiology pharmacy, and pharmacy department among seven items, whereas Cluster 2 demonstrated the Centre for Pharmacoinformatic comprised an association with the medical intensive care unit.

Table 7. Authorship analysis

| Author's name | Affiliation                             | Country       | TP | NCP | TC | C/P  | C/CP | h | g |
|---------------|-----------------------------------------|---------------|----|-----|----|------|------|---|---|
| Donnelly, J.  | Three Rivers Community College          | USA           | 10 | 7   | 34 | 3.40 | 4.86 | 4 | 5 |
| Hanes, F.     | New England Board of Higher Education   | USA           | 7  | 7   | 34 | 4.86 | 4.86 | 4 | 5 |
| Juandi, D.    | Universitas Pendidikan Indonesia        | Indonesia     | 6  | 6   | 26 | 4.33 | 4.33 | 3 | 5 |
| Massa, N. M.  | Springfield Technical Community College | United States | 6  | 6   | 21 | 3.50 | 3.50 | 3 | 4 |
| Suparman      | Universitas Ahmad Dahlan                | Indonesia     | 5  | 4   | 15 | 3.00 | 3.75 | 2 | 3 |

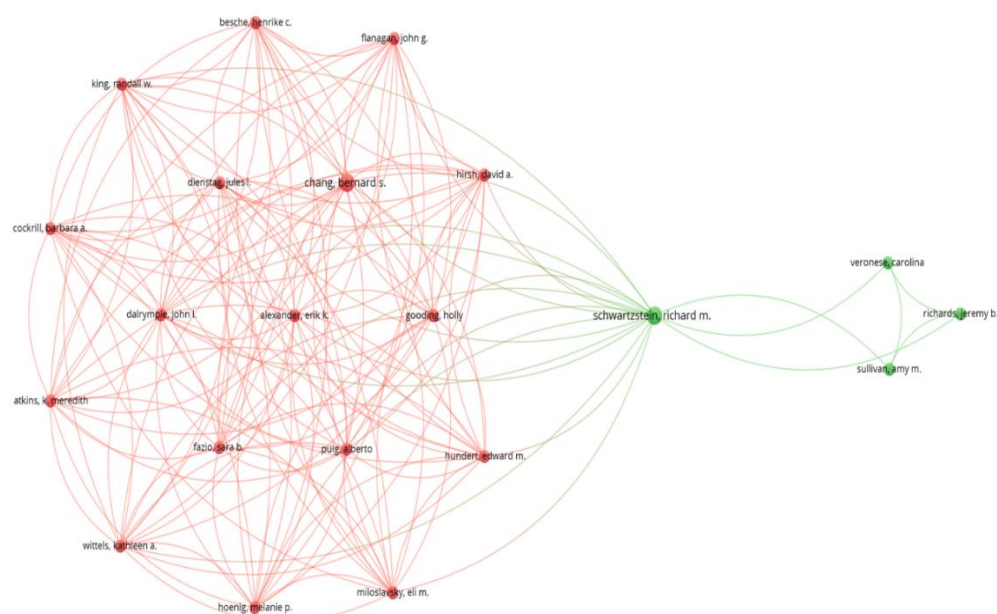


Figure 3. A co-authorship network visualization map based on authors



Figure 4. A co-authorship network visualization map based on organizations

### 3.7. Most active institutions

Table 8 demonstrates the five top-performing institutions on PBL and CT publications, with three Indonesian universities playing an integral role in publishing 16 and 15 documents respectively, followed by the University of Hong Kong and the University of the United States. Furthermore, Hong Kong Polytechnic University achieved a significantly high C/P and C/CP compared to other institutions due to the significant contribution and impact on the academic community and PBL and CT topics.

Table 8. The top five most active institutions on PBL and CT publications

| Institutional                        | Country       | TP | NCP | TC  | C/P   | C/CP  | h | g  |
|--------------------------------------|---------------|----|-----|-----|-------|-------|---|----|
| Universitas Pendidikan Indonesia     | Indonesia     | 16 | 13  | 79  | 4.94  | 6.08  | 6 | 8  |
| Universitas Negeri Yogyakarta        | Indonesia     | 15 | 13  | 172 | 11.47 | 13.23 | 6 | 13 |
| Universitas Negeri Malang            | Indonesia     | 15 | 14  | 134 | 8.93  | 9.57  | 7 | 11 |
| The Hong Kong Polytechnic University | Hong Kong     | 12 | 12  | 485 | 40.42 | 40.42 | 9 | 12 |
| Three Rivers Community College       | United States | 12 | 9   | 40  | 3.33  | 4.44  | 4 | 5  |

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; and g=g-index.

### 3.8. Keywords analysis

Keyword selection is a crucial factor in document search as databases and academic repositories utilize specific keywords to index and categorize articles. Appropriately selected keywords assist in accurately classifying articles, which increases the efficiency of researchers, students, and professionals in locating relevant literature. Figure 5 illustrates a visualization network of keywords with a minimum of two occurrences. A total of 31 clusters with 367 items in PBL and CT research were generated based on author keywords. The diagram displays the most frequently employed keywords, such as PBL, active learning, nursing education, andragogy, teaching innovation, pharmacy law, sustainability, inductive reasoning, digital processing, and CT skills. Comparatively, other keywords, including business research process and bioinformatics, consisted of weak connections with other keywords. Table 9 presents the top 20 keywords commonly utilized by writers.

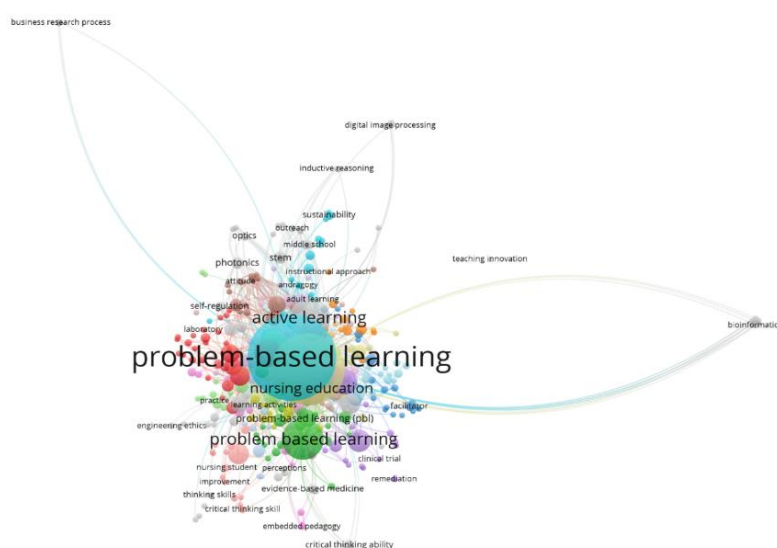


Figure 5. A network visualization map of co-occurrences based on author keywords







### 3.11. Title field

Figure 7 illustrates the visualization of a term title field with a minimum of two occurrences. The binary counting method was applied, resulting in 21 clusters with 212 items were produced. The primary term identified was ‘thinking skill’, which is the main topic and comprises a robust relationship with other terms, namely perspective, web, framework, student learning, and improvement.

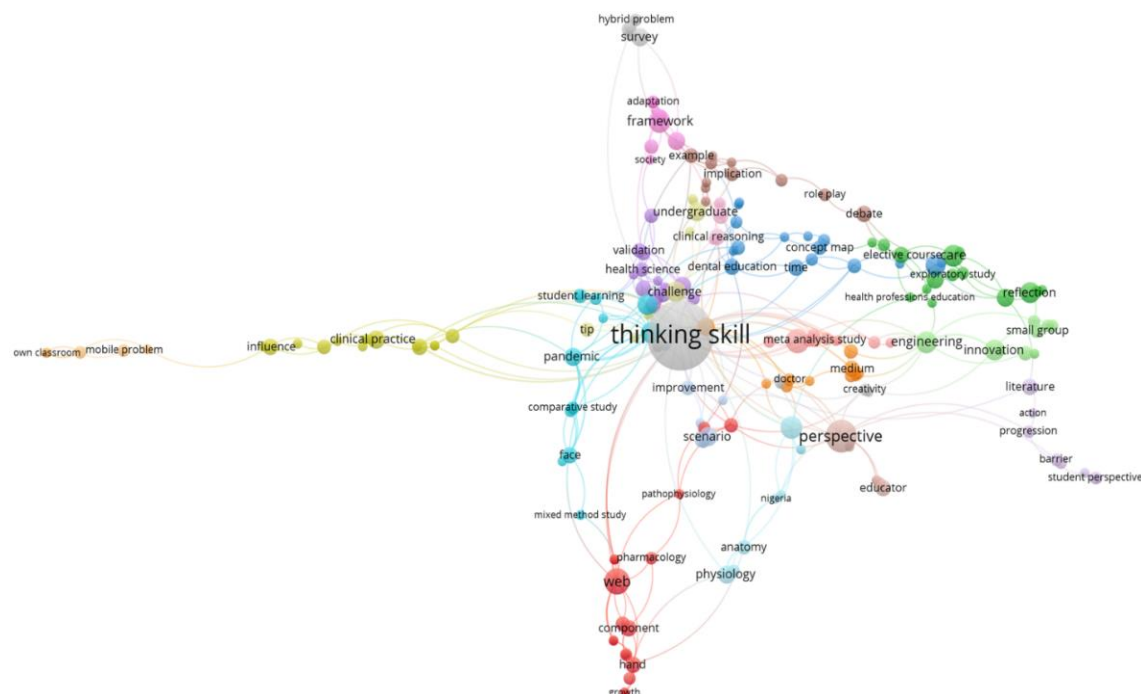


Figure 7. VOSviewer visualization of a term co-occurrence network based on title fields

## 4. DISCUSSION

The PBL concept originated in the late 1960s from medical schools at McMaster University in Canada [39]. Dr Howard Barrows and colleagues developed PBL as a teaching method for medical students, which was subsequently adopted in various educational fields worldwide, including social sciences, healthcare, medicine, and engineering. The PBL and CT are two popular approaches in various fields, with PBL employed extensively as an effective method to enhance CT [40] and foster a deep understanding and analytical skills in students. Particularly, PBL immerses students in real-world situations [7], [41] and encourages the students to collaboratively identify and resolve complex challenges [42]. Meanwhile, CT is the capacity to objectively analyze information, evaluate arguments, and perform reasonable judgments [43]. As such, both PBL and CT complement one another to produce a significant impact [20], [44]. The current study conducted a bibliometric analysis from 1975 to 2023 (48 years) to address three research questions, namely the current PBL and CT trends and publication impacts, the most productive and influential countries, institutions, and authors in the field, and the most common PBL and CT themes employed among scholars.

The present study found that the integration of PBL and CT has attracted significant researchers' attention, although the number of publications decreased in 2022 and 2023 compared to 2019, 2020, and 2021 which prioritized the integration of PBL and CT. This study also discovered that PBL was the primary approach employed in teaching to develop students' CT, problem-solving, and communication skills. The finding was consistent with [43], who demonstrated that most studies were conducted to understand CT skills in PBL. Additionally, the publication type with the highest number was articles as the peer review process before publication encourages researchers to contribute high-quality content. Various languages were also utilized to publish documents, including English, Spanish, Portuguese, and Chinese, with English as the dominant language. English is an international language that serves as the primary medium for publications, which assists in elevating the citation number [45].

Meanwhile, the VOSviewer results revealed that the USA led in terms of publication quantity and impact compared to other countries despite PBL being introduced in Canada. The PBL aligns with the USA

educational philosophy, which emphasizes student-centered learning [46], including active engagement, CT, and problem-solving skills [47]. Researcher analysis also demonstrated that Donnelly, J., from Three Rivers Community College, Juandi, D., from Universitas Pendidikan Indonesia, Hanes, F., from the New England Board of Higher Education in the USA, and Massa, N. M., from Springfield Technical Community College in the USA were researchers with the highest publication number. The USA comprises a robust infrastructure for academic publications with various academic journals and publishers specializing in research. The facilities provide multiple opportunities to disseminate PBL and CT findings. Active and influential Indonesian institutions also included Universitas Negeri Malang, Universitas Negeri Yogyakarta, and Universitas Pendidikan Indonesia, apart from Hong Kong Polytechnic University and Three Rivers Community College from the USA. Furthermore, Hong Kong Polytechnic University achieved a high citation number compared to other institutions owing to the high focus on CT development among students. Teaching methods also encouraged students to develop communication and problem-solving skills [48].

Appropriately selected keywords assisted in accurately classifying articles, which allowed higher efficiency for researchers, students, and professionals to locate relevant literature. Commonly employed PBL and CT keywords encompassed PBL, active learning, nursing education, andragogy, teaching innovation, pharmacy law, sustainability, inductive reasoning, digital processing, and CT skills. Furthermore, educational development in the 21st century has produced several most frequently employed keywords by researchers. Researchers are interested in exploring alternative pedagogical approaches, such as PBL, to enhance student learning outcomes and foster CT abilities [40]. In addition, high publication source titles in PBL and CT were discovered in the Journal of Physics Conference Series, Journal of Dental Education, Journal of Nursing Education, Nurse Education Today, and Nurse Education in Practice with high-quality documents. Journals are significant contributors to the academic and contain high citation rates as journals implement strict peer-review processes to ensure that published articles fulfil high academic standards. Resultantly, researchers focusing on PBL and CT published research work in reputable journals to gain recognition and validation from peers [29].

Title and abstract analysis also revealed commonly utilized terms, such as engineering, mathematics, PBL model, and web, as PBL is a popular teaching methodology commonly across various disciplines, including engineering and mathematics. Researchers could explore effective methods to implement PBL in the curriculum to enhance students' CT and problem-solving capabilities [49]. Moreover, common topic fields in PBL and CT document publications included thinking skills, perspective, web, framework, student learning, and improvement, which indicated the primary aim of improving the understanding of effective PBL to develop CT and encourage learning [50].

## 5. CONCLUSION

The present study examined the PBL and CT trends and patterns by focusing on annual publications, document types, document languages, source types, and subject areas. The data were acquired from the Scopus database and investigated via bibliometric analysis conducted on VOSviewer, POP, and Microsoft Excel 365 software. The results demonstrated an increased focus by researchers on PBL and CT, with a significantly high number of publications in 2021. Articles (document type), journals (source type), English (document language), and social sciences (subject area), were also demonstrated to be the most popular aspects in PBL and CT publications. In addition, the USA (country), Donnelly, J. (researcher), Universitas Pendidikan Indonesia (active institution), PBL (keywords), Physics Conference Series Journal (source title), engineering (title and abstract), thinking skill (title field) were the focus areas with high interest in the PBL and CT field. Summarily, high opportunities are provided for future researchers to perform in-depth exploration of the topic.

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## AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

| Name of Author         | C | M | So | Va | Fo | I | R | D | O | E | Vi | Su | P | Fu |
|------------------------|---|---|----|----|----|---|---|---|---|---|----|----|---|----|
| Yogalingam Subramaniam | ✓ | ✓ | ✓  | ✓  | ✓  | ✓ |   | ✓ | ✓ |   | ✓  |    | ✓ |    |
| Muzirah Musa           | ✓ | ✓ |    | ✓  | ✓  |   | ✓ | ✓ |   | ✓ | ✓  | ✓  | ✓ | ✓  |

C : Conceptualization

M : Methodology

So : Software

Va : Validation

Fo : Formal analysis

I : Investigation

R : Resources

D : Data Curation

O : Writing - Original Draft

E : Writing - Review & Editing

Vi : Visualization

Su : Supervision

P : Project administration

Fu : Funding acquisition

## CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

## DATA AVAILABILITY

Data availability is not applicable to this study, as no new data were generated or analyzed.

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## APPENDIX

Table 1. Annual publication growth

| Year | TP  | %    | NCP | TC   | C/P   | C/CP  | h  | g  |
|------|-----|------|-----|------|-------|-------|----|----|
| 2024 | 1   | 0.09 | 0   | 0    | 0.00  | 0.00  | 0  | 0  |
| 2023 | 66  | 5.95 | 24  | 50   | 0.76  | 2.08  | 3  | 4  |
| 2022 | 66  | 5.95 | 46  | 173  | 2.62  | 3.76  | 6  | 9  |
| 2021 | 109 | 9.83 | 91  | 714  | 6.55  | 7.85  | 13 | 22 |
| 2020 | 101 | 9.11 | 94  | 671  | 6.64  | 7.14  | 15 | 19 |
| 2019 | 87  | 7.84 | 69  | 533  | 6.13  | 7.72  | 11 | 19 |
| 2018 | 60  | 5.41 | 50  | 868  | 14.47 | 17.36 | 16 | 27 |
| 2017 | 56  | 5.05 | 49  | 927  | 16.55 | 18.92 | 17 | 28 |
| 2016 | 51  | 4.60 | 45  | 671  | 13.16 | 14.91 | 14 | 24 |
| 2015 | 64  | 5.77 | 61  | 1592 | 24.88 | 26.10 | 22 | 38 |
| 2014 | 43  | 3.88 | 39  | 908  | 21.12 | 23.28 | 16 | 29 |
| 2013 | 37  | 3.34 | 32  | 855  | 23.11 | 26.72 | 16 | 29 |
| 2012 | 47  | 4.24 | 42  | 963  | 20.49 | 22.93 | 18 | 30 |
| 2011 | 33  | 2.98 | 29  | 771  | 23.36 | 26.59 | 15 | 27 |
| 2010 | 46  | 4.15 | 46  | 1383 | 30.07 | 30.07 | 20 | 36 |
| 2009 | 43  | 3.88 | 37  | 797  | 18.53 | 21.54 | 14 | 27 |
| 2008 | 40  | 3.61 | 37  | 1159 | 28.98 | 31.32 | 20 | 33 |
| 2007 | 25  | 2.25 | 25  | 1067 | 42.68 | 42.68 | 14 | 25 |
| 2006 | 32  | 2.89 | 27  | 1125 | 35.16 | 41.67 | 15 | 27 |
| 2005 | 23  | 2.07 | 22  | 1156 | 50.26 | 52.55 | 12 | 22 |
| 2004 | 15  | 1.35 | 15  | 376  | 25.07 | 25.07 | 9  | 15 |
| 2003 | 11  | 0.99 | 10  | 231  | 21.00 | 23.10 | 7  | 10 |
| 2002 | 7   | 0.63 | 7   | 185  | 26.43 | 26.43 | 6  | 7  |
| 2001 | 8   | 0.72 | 6   | 157  | 19.63 | 26.17 | 4  | 6  |
| 2000 | 6   | 0.54 | 6   | 406  | 67.67 | 67.67 | 4  | 6  |
| 1999 | 9   | 0.81 | 8   | 367  | 40.78 | 45.88 | 7  | 8  |
| 1998 | 9   | 0.81 | 9   | 204  | 22.67 | 22.67 | 7  | 9  |
| 1997 | 7   | 0.63 | 5   | 57   | 8.14  | 11.40 | 4  | 5  |
| 1996 | 4   | 0.36 | 4   | 37   | 9.25  | 9.25  | 4  | 4  |
| 1995 | 3   | 0.27 | 2   | 10   | 3.33  | 5.00  | 2  | 2  |

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; and g=g-index.

## BIOGRAPHIES OF AUTHORS



**Yogalingam Subramaniam**    is currently a student of PhD in educational studies, Universiti Sains Malaysia. He received a bachelor of science (honours) in mathematics from Universiti Sains Malaysia, in 2010 and a master of education in instructional technology from Universiti Utara Malaysia, in 2018. He has 20 years of teaching experience in education and his area of expertise are mathematics education and technology. He can be contacted at email: yogal\_03@edidik.edu.my.



**Muzirah Musa**    is currently a senior lecturer at the school of educational studies, Universiti Sains Malaysia. She received a bachelor of science (honours) in mathematics from Universiti Sains Malaysia, in 2001 and a master of science in statistics from the same institution, in 2002. Her academic excellence continued as she achieved a doctor of philosophy in statistics from the Universiti Kebangsaan Malaysia, in 2014. She has 21 years of teaching experience in higher education and her area of expertise are statistics, mathematics education and STEM education. She has a good consulting background in the fields of mathematics education and statistics, providing expert advice and insights to various educational institutions. Her consulting work includes assessing a curriculum design for mathematics education program in teacher's institution, and conducting workshops and training sessions for educators to enhance their teaching methodologies. She also does consultation in statistical analysis for postgraduate students and researcher to enhance their statistical methodologies. She can be contacted at email: muzirah@usm.my.